THREE-BODY ABRASIVE WEAR BEHAVIOUR OF JUTE-GLASS REINFORCED EPOXY COMPOSITE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology in Mechanical Engineering

By

SWARUPA RANJAN PATI
ROLL No. : 111ME0330

Under the Guidance of

Prof. S.K. Acharya

DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
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CERTIFICATE

This is to certify that the thesis entitled in **"Three-Body Abrasive Wear Behavior of Jute-Glass Reinforced Epoxy Composites"** submitted by **SWARUPA RANJAN PATI** (Roll No. **111ME0330**) in partial fulfillment of the requirement for the award of **Bachelor of Technology** to the Department of Mechanical Engineering, National Institute of Technology, Rourkela is an authentic work carried out under my supervision and guidance.

To best of my knowledge, the matter used in the thesis has not been submitted to elsewhere for the award of any degree.

Place: Rourkela

Date:

Prof. S.K. Acharya
Dept. of Mechanical Engineering
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Rourkela-769008

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Last, but not least, I thank my parents for giving me life in the first place, for educating me with aspects from both arts and sciences, for unconditional support and encouragement to pursue my interests.

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ABSTRACT

Natural polymers reinforced with synthetic fibers such as glass, carbon, and aramid provide advantages of high stiffness and strength to weight ratio as compared to conventional materials. The thought of composite materials is not a new one to discuss. Nature is a full of composite materials which we regularly see and use. common fiber reinforced with polymer matrix have got the consideration worldwide because of their low cost, minimal effort, lightweight, renewability, combustibility,low density and biodegradability. Very large numbers of natural elements are available which can be used as reinforcement, for example, jute, and banana, rice husk which have turned out to be great and proficient fortifications. Fiber Reinforced Polymer (FRP) composites are known as the most advanced kind of composites. They are exceptionally efficient in terms of their minimal cost, high quality, strength and mechanical properties. Despite of the fact that FRP composites have particular disadvantages like low working temperature, high coefficient of thermal and moisture expansion, low elastic properties, still they are very helpful. The present work includes study of hybrid natural fibers and fabrication of hybrid natural composites of jute and glass with different stacking sequence. It also includes testing of the composites to study the three-body abrasive wear behavior and microscopic analysis of the abraded surface.

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INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 MOTIVATION

It is practiced that innovative improvement depends upon developments in the field of materials. One need not necessarily have to understand the basic concepts of most developed turbine or air-craft design. Technology is of no application if reasonable materials to manage the administration loads, conditions and requirement are not accessible. Whatever the field is the last constraint on evolution trusts on upon materials. Composite materials in this respect speak to only a necessary venture in the attempt of development in materials.

The thought of composite materials is not a new one to discuss. Nature is a full of composite materials which we regularly see and use. For example, the coconut palm leaf is a cantilever utilizing the idea of fiber protection. Wood is also a fibrous composite where cellulose constituents in a lignin linkage. The cellulose filaments have high elasticity still they are exceptionally adaptable because of low stiffness while the lignin grid joins the parts and outfit the solidness. Bone is also another illustration of a common composite has backs the weight of different parts of the body. It consists of short and delicate collagen strands inserted in a mineral network called apatite. Nevertheless these characteristically composites, there are numerous other materials that are composites in an exceptionally general manner and that have been being used for long time. The carbon dark in elastic or black-top mixed with sand, and glass filaments in pitch are regular illustrations. Therefore, we see that the thought of composite materials is not that old. All things considered, one can securely cast the foundation of the different control of the composite materials as the start of the 1960's. It might not be completely wrong to say that a coordinated innovative work application in composite materials started in 1965. Since the early 1960's, there has been a growing interest for materials that are stiffer and stronger also lighter in fields as differing as aviation, energy infrastructure and civil developments.

1.2 COMPOSITE MATERIAL:-

Generally, a composite material is composed of reinforcement (fibers, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material.

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials combined together to give the composite unique properties. However, within the composite we can easily tell the different materials apart as they do not dissolve or blend into each other. In composite materials the materials never lose their properties unlike the alloys.

There are generally three types of composite material relying upon the matrix material utilized.

- Metallic composite
- Polymeric composite
- Ceramic composite

Lately, common fiber reinforced with polymer matrix have gotten the consideration worldwide because of their low cost, minimal effort, lightweight, renewability, combustibility ,low density and biodegradability. Very large numbers of natural elements are available which can be used as reinforcement, for example, jute, and banana, rice husk which have turned out to be great and proficient fortifications. Fiber Reinforced Polymer (FRP) composites are known as the most advanced kind of composites. They are exceptionally efficient in terms of their minimal cost, high quality, strength and mechanical properties. Despite of the fact that FRP composites have particular disadvantages like low working temperature, high coefficient of thermal and moisture expansion, low elastic properties, still they are very helpful.

As well as strength is concerned, natural fibers possess a substantial weight fraction in FRP composite as they need to convey most extreme measure of a load when the load acts on the composite. The simplicity of accessibility and manufacturing have attracted researchers to utilize provincially accessible cheap fibers .There have been research going on the field to test their use as reinforcement and the degree up to which they can satisfy the particulars of reinforced polymer composites for tribological requisitions.

1.3 NATURAL FIBER COMPOSITE:-

Generally the term "natural fiber" covers a broad range of vegetables, animals and mineral fibers. But in the composite industry, it refers to wood fiber, leaf, seed, and stem fibers. These fibers normally contribute greatly to the structural performance of plant. They can provide significant reinforcement when used in plastic composites.

In spite of the interest and environmental appeal of natural fibers, their use is limited to non-bearing applications due to their lower strength compared to synthetic fiber reinforced polymer composite. The stiffness and strength of bio composites can be improved by structural configurations and better arrangement by placing the fibers in specific locations for higher strength performance. Hence extensive studies on preparation and properties of polymer matrix composite (PMC) is replacing the synthetic fiber with natural fibers like Jute, Sisal, Pineapple, Bamboo and Kenaf .

1.3.1 Advantages of Natural fiber Over Synthetic Fiber :-

- They can be easily available, mainly in ASIA.
- The manufacturing process of natural fiber composite is very simple and easy.
- It is not very expensive than the synthetic fibers.
- They are low density materials which makes them light weight with high specific properties.
- Natural fibers are renewable and bio-degradable which is the most important advantage of natural fiber over synthetic fiber.

1.3.2 Disadvantages of Natural Fibers:-

- Mechanical properties (i.e. strength, toughness) of natural fiber composites are much lower than those of synthetic fiber composites.
- They have poor resistance to moisture absorption which makes them less attractive.

1.4 HYBRID COMPOSITES:-

Hybrid composites are composites consisting of two constituents at the nanometer or molecular level. Commonly one of these compounds is inorganic and the other one organic in nature. Thus, they differ from traditional composites where the constituents are at the macroscopic (micrometer to millimeter) level. Mixing at the microscopic scale leads to a more homogeneous material that either shows characteristics in between the two original phases or even new properties.

The first hybrid materials were the paints made from inorganic and organic components that were used thousands of years ago. Rubber is an example of the use of inorganic materials as fillers for organic polymers. The sol–gel process developed in the 1930s was one of the major driving forces what has become the broad field of inorganic–organic hybrid materials.

Hybrid bio composites can be designed by the combination of a synthetic fiber and natural fiber (bio-fiber) in a matrix and a combination of two natural fiber / bio-fiber in a matrix. Hybridization with glass fiber provides a method to improve the mechanical properties of natural fiber composites and its effect in different modes of stress depends on the design and construction of the composites.

1.5 JUTE FIBER:-

Jute is a popular plant in the corchorus class. The major types are popularly known as white jute and tossa jute. Jute is grown mainly in Asian countries like India and Bangladesh which is harvested at 2 to 3 months of growth, at which time it is 3-5 meters tall. Jute has a terse cover, known as jute stick and the blast fibers normally grow lengthwise around its core. Jute blast fiber is separated from the pith by retting process. Retting is done by placing cut jute stalks inside the ponds for several weeks. Microbial effect of the pond softens the jute fiber and weakens the bonds between the individual fiber and the pith. Then the fiber stands are manually stripped from the jute stick and hung on ways to dry. The fibers obtained by this way are very long. These are also treated with various oils or conditioners to increase flexibility, the retted jute fiber stands are suitable for manufacturing of textiles.

As shown in figure 1 below Jute is a multi-celled in structure. The cell wall of a jute fiber is made of a number of layers, these are called primary wall (the first layer deposited during cell development) and the secondary wall (S), which again is made of three layers (S1, S2 and S3**).** These layers mainly contain cellulose, hemicelluloses and lignin in varying amounts almost in all lignocellulose fibers. A lignin-rich region known as the middle lamella bonds the individual fibers. Cellulose has highest concentration in the S2 layer (about 50%) and lignin is most intense in the middle lamella (about 90%) which is free of cellulose.

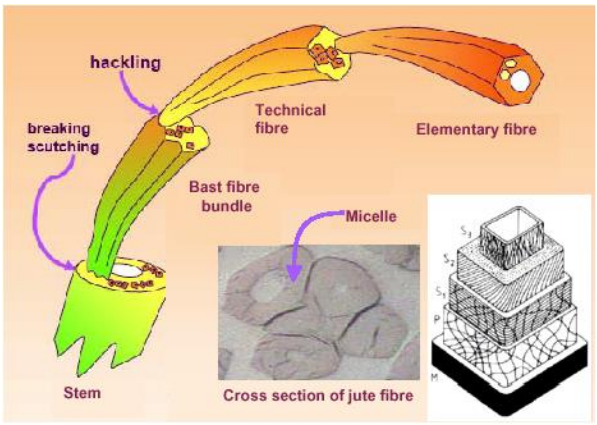

Fig. 1 (Scheme of jute fiber structure)

Hemicelluloses are found in all jute fibers. Hemicelluloses are polysaccharides bonded together in relatively short, branching and regular chains. They are also closely associated with the cellulose micro fibrils, embedding the cellulose in a matrix. Hemicelluloses are very hydrophilic and they also have lower molecular masses than both cellulose and lignin. Xylene and Glucomannans are two main types of hemicelluloses.

Composition of Jute Fiber

Substances	Weight percent (%)
Cellulose	61-71.5
Hemicellulose	13.6-20.40
Pectin	0.2
Lignin	12-13
Moisture content	12.6
Wax	0.5

1.6 GLASS FIBER:-

There are variety of different chemical compositions of glass fibers are commercially available. Commonly available glass fibers are silica based (50-60% SiO_2) and contains other oxides of calcium boron, sodium, aluminum, and iron, The composition of some common used glass fibers are shown in the below table.

Glass fibers are amorphous solids composed primarily of silica backbone in the form of (-SiO4)n tetrahedral. It is the most common reinforcing material for polymer matrix composites as they offer high strength at relatively low cost. They are available as continuous and short fibers. However they have poor abrasion resistance, poor adhesion to polymer matrix resins and tendency to absorb moisture. Coupling agents (e.g.silanes) are used to overcome these drawbacks. There are five major type of glass used for making fibers. The letter designation is taken from the characteristic property:

(i) A-glass is a high-alkali glass. This offers good resistance to chemical, but lower electrical properties.

(ii) C-glass is a chemical glass, a special mixture with extremely high chemical resistance.

(iii) E-glass is an electrical grade with low alkali content. It has good insulation property and strongly water resistance.

(iv) S-glass is a high strength glass with 33% higher tensile strength then E-glass.

(v) D-glass has a low dielectric constant with superior electrical properties.

E-glass fiber which dominates the current FRP industries has very good mechanical and electrical characteristics at a reasonable cost. S-glass contains a higher percentage of alumina and silica as compared to E-glass.

Chemical Composition of Some Glass Fibers

composition	E glass	C glass	S glass
SiO_2	55.4	65.2	65.2
Al_2O_3	8.0	4	25.0
CaO	18.8	14.0	_
MgO	4.6	3.0	10
Na_2O	0.3	8.5	0.3
K_2O	0.2	-	_
B_2O_3	7.2	5.0	_

PRESENT WORK:-

In this paper, abrasive wear behavior of JUTE-GLASS composite is studied. Hence, first manufacturing of composites with different stacking sequence will be done and then they will be tested in a DRY SAND RUBBER WHEEL RIG for abrasive wear.

Chapter 2

LITERATURE SURVEY

CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE SURVEY:-

A literature survey is a proof essay of sorts. It is a study and review of relevant literature materials in relation to a topic you have been given. It is the documentation of a comprehensive review of the published and unpublished work from secondary sources data in the areas of specific interest to the researcher.

2.2 JUTE-GLASS COMPOSITE:-

There is frequent application of natural fiber composite in regular life. For example, jute is a typical reinforcement for composites in India. Jute filaments as matrix with epoxy resins are utilized within structures, lifts, pipes, panels and construction. Natural fiber composites can also be exceptionally knowledge material for application in building and other construction purposes (e.g. walls, roof, parcel, window and entryway outlines), stockpiling gadgets (e.g. bio-gas compartment, post boxes, and so on.), furniture (e.g. seat, table, instruments, and so forth.), electronic cells(outer casting of cell telephones), automobile and railway coach interior parts (inward bumpers and guards), toys and different random provisions (head protectors, suitcases).

Wacker G.et [5].al described the influence of fiber content on the dynamic modulus of jute/epoxy composites with both untreated and alkali treated jute fibers. Their results implied slower damage growth of the composites with NaOH treated fibers.

Dipa Ray, K Sarkar ,S Das ,AK Rana [6] also studied Vinyl –resin –matrix reinforced with both untreated and 5% NaOh treated jute fibers for 4 and 8 hrs respectively with different fiber loading subjected to vibrant mechanical and thermal analysis. He also determined their dynamic properties as a function of temperature. Their results showed that for all the composites, with a significant fall in the temperature (110^0C-170^0C) the storage modulus decreases.

Rana[9] gave a comparison between the jute fiber as a reinforced material and glass fiber . He concluded that this natural fiber has some draw backs and needs chemical modification for enhancement in properties.

Rana et al.[9] studied the DTM behavior of short jute-fiber-reinforced polypropylene composites and observed the effect of compatibility on the duynamic properties of the composts. They also observed that the loss-modules increases and higher temperatures with the increase of the fiber loading of the composites. The efficiency of the compatibility system was more prominent at higher temperatures and at higher fiber loading. He reported a small hump at a temperature higher than the glass transition temperature (Tg) and explained that its movement towards the Tg of the dry cellulose (200^0 C).

Mohanty et al has done the study of the potential of jute fiber as an alternative reinforcement to traditional man-made fibers in fiber reinforced plastics by adding natural fibers into it.

2.3 THREE-BODY ABRASIVE WEAR:-

Abrasive wear is one type of wear where hard asperities on one surface move across a softer surface under load, which penetrate and removes material from the softer surface, leaving behind, and grooves. Abrasive wear can occur as two-body abrasion, three-body abrasion, or both. Three-body abrasive wear is caused by interactions of hard asperities (hard debris or foreign particles trapped between the polymer and the mating surface) on one surface, which move across a softer surface and also leave grooves on the softer surfaces that may further increase or decrease the wear rate by several orders. Most of the abrasive wear problems which arise in general engineering or machine components, involve three-body wear, while two-body abrasion occurs primarily in material removal operations.

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Suresha et. al showed that inclusion of particulate SiC filled glass fabric–vinyl ester composite gives better abrasive wear performance when compared to graphite filled composite system. He also reported that inclusion of particulate SiC into epoxy matrix, improves its wear resistance.

Mohan et.al studed the effect of addition of tungsten carbide (WC) and tantalum niobium carbide on three-body abrasive wear behavior of glass fabric–epoxy composites.

Lhymn et al. studied the abrasive wear behavior of short carbon fiber (CF) reinforced PEEK. Voss and Friedrich studied the sliding and abrasive wear behavior of short glass and Carbon Fiber reinforced PEEK composites at room temperature..

Harsha and Tewari had also done investigation on two-body abrasive wear behavior of various short fibers reinforced PAEK composites. Their above study was concentrated on two-body abrasion studies of PAEKs and also their composites against abrasive papers.

Yousif et al. studied the three-body abrasive wear behavior of sliced strand mat glass fibers reinforced polyester (CGRP) composite in different fiber orientation and summarized that CGRP showed better wear resistance in parallel orientation than all other types of orientations. He also concluded that fillers and fiber reinforcements also play an important role while determining the abrasive wear the polymer matrix composites.

Suresha et al. studied the three-body abrasive wear of silicon carbide (SiC) filled in glass fabric reinforced epoxy (G-E) composites. He found that SiC decreases the specific wear rate of G-E composite.

Chapter 3

MATERIALS & FABRICATION

CHAPTER 3

3. MATERIALS & FABRICATION

In this chapter we will discuss about the fabrication of the composites by HAND LAY-UP technique followed by testing them in the DRY-SAND ABRASIVE WEAR RIG machine to study wear behavior.

The raw materials used in the fabrication process are:-

a) JUTE as Natural Fiber
b) GLASS
c) Epoxy resin
d) Hardener

EPOXY RESIN:-

The low temperature curing epoxy resin **Araldite LY556** having the following properties was used.

1) Excellent adhesion to different materials.
2) Great strength and toughness.
3) Excellent resistance to chemical attack and moisture.
4) Excellent mechanical and electrical properties.
5) Odorless, tasteless and completely non-toxic.
6) Negative shrinkage.

HARDENER:-

In the present work hardener **HY 951** is used. It has a viscosity of 10-20 poise at 20^0C

Silicone Spray:-

As silicone spray is super slippery, it is used on the sheets used for casting for non-sticking purpose. The other advantage of silicone spray is that it is non-reactive.

3.1 FABRICATION OF COMPOSITE FIBER BY HAND LAY-UP TECHNIQUE:-

Here, we will use Hand Lay-up technique for the manufacturing of composites.

- It is the simplest and oldest open molding method of the composite fabrication process.
- It is the most economical process of making small to large parts.
- It also utilizes low-cost tooling as well as low cost material system.

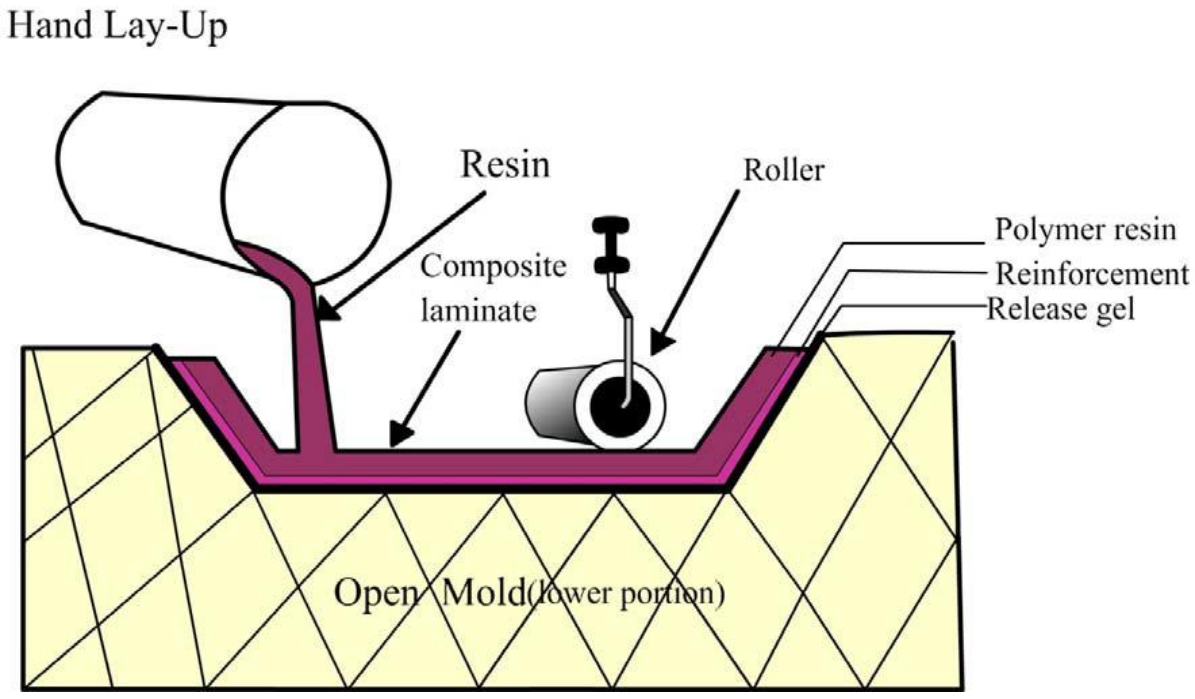


Fig. 2(HAND LAY-UP TECHNIQUE)

3.1.1 Fabrication Process:-

- As 10 layer composites of different stacking sequence of jute and glass are to be fabricated, so total number of jute (44) and glass (26) were cut from the sheet.
- The required sample dimension should be 75mm×25mm, so the dimension of mold was made larger than the sample.
- The dimension of mold was set as 76mm×50mm×13mm.
- So, the jute and glass fibers of dimension 76mm×50mm were cut from the given sheet.
- The wooden mold as shown in fig.2 is formed on the wooden ply board.

Fig. 3 (WOODEN MOLD)

- The wooden sticks were clamped to form the mold on a plastic sheet so that it will give proper polished product.
- Silicone spray was sprayed inside the mold to make it slippery and for easy removal of the final product.
- For each composite amount of epoxy resin were calculated by taking the volume of the mold. Hardener of $1/10^{th}$ of the weight of the epoxy resin was taken.
- The epoxy resin and hardener were mixed properly for at least 5 minutes.
- Then the mixture is poured inside the mold to form a small layer of resin (as shown in fig. 1).
- Then the prepared jute and glass pieces were stacked according to the required stacking sequence.
- The layers were placed one over the other with proper resin layer in between them.
- After that the mold is covered by a transparent sheet and a card board on it.
- Then the mold is pressed by weights (as shown in fig. 3) so that there would be no gas bubbles inside the mold.
- The mold was left for at least 48 hours before removing the composite from it.
- The composites are removed carefully so that no damage or crack will occur to the composites.

Fig. 4(Weights loaded during fabrication) **Fig.5(SILICONE SPRAY)**

3.1.2 CALCULATION OF VOLUME FRACTION & WEIGHT FRACTION:-

- Volume of mold =V_{mold}= L×b×t = 7.6×5.0×1.3 cm^3 = 49.4 cc
- Density of jute, ρ_j = 1.5 gm/cc
- Density of glass fiber = ρ_g =2.5 gm/cc
- Density of epoxy = ρ_{epoxy} = 1.1 gm/cc
- Volume fraction of fiber = (V_j + V_g / V_j + Vg + V_m)×100
- Weight fraction of fiber = (W_j + W_g/ W_j + W_g + W_m + W_h)×100

S1 (JJJJJJJJJJ):- Only Jute

Weight of Jute (10layer) =W_j= 8.6 gm

Volume of Jute (V_j)= 8.6/ρ_j = 8.6/1.5=5.73 cc

Volume of matrix= V_m= V_{mold} – V_j = 43.66 cc

Weight of matrix =W_m= V_m× ρ_m= 43.66×1.1= 48.026 gm

Weight of hardener = W_h= W_m/10 =4.8 gm

Volume fraction of fiber = V_{fiber}/V_{mold} = 5.73/49.4= 11.6 %

Weight fraction of fiber = (W_j / W_j + W_m + W_h)×100 = 14 %

S2 (GJJJJJJJG):- 80% Jute, 20% Glass

Weight of Jute =W_j= 7.12 gm

Weight of Glass =W_g = 2.5 gm

Volume of Jute (V_j)= 7.12/ρ_j = 7.12/1.5= 3.33 cc

Volume of Glass(V_g)= 2.5/ρ_g = 2.5/2.5= 1 cc

Volume of matrix= V_m= V_{mold} – V_j = 45 cc

Weight of matrix =W_m= V_m× ρ_m= 45×1.1= 49.5 gm

Weight of hardener = W_h= W_m/10 = 5 gm

Volume fraction of fiber = V_{fiber}/V_{mold} = 4.33/49.4= 8.76 %

Weight fraction of fiber = (W_j + W_g/ W_j + W_g + W_m + W_h)×100 = 14.88 %

S3 (GGJJJJJJGG):- 60% Jute, 40% Glass

Weight of Jute =W_j= 5 gm

Weight of Glass =W_g = 4.8 gm

Volume of Jute (V_j)= 5/ρ_j = 5/1.5= 3.33 cc

Volume of Glass(V_g)= 4.8/ρ_g = 4.8/2.5= 1.92 cc

Volume of matrix= V_m= V_{mold} – V_j = 44.18 cc

Weight of matrix =W_m= V_m× ρ_m= 44.18×1.1= 48.56 gm

Weight of hardener = W_h= W_m/10 = 4.856 gm

Volume fraction of fiber = V_{fiber}/V_{mold} = 3.33 + 1.92/49.4= 10.62 %

Weight fraction of fiber = (W_j + W_g/ W_j + W_g + W_m + W_h)×100 = 15.5 %

S4 (GGGJJJJGGG):- 40% Jute, 60% Glass

Weight of Jute =W_j= 3.4 gm

Weight of Glass =W_g = 7.8 gm

Volume of Jute (V_j)= 3.4/ρ_j = 3.4/1.5= 2.267 cc

Volume of Glass(V_g)= 7.8/ρ_g = 7.8/2.5= 3.12 cc

Volume of matrix= V_m= V_{mold} – V_j = 44 cc

Weight of matrix =W_m= V_m× ρ_m= 44.18×1.1= 48.4 gm

Weight of hardener = W_h= W_m/10 = 4.84 gm

Volume fraction of fiber = V_{fiber}/V_{mold} = 2.267 + 3.12/49.4= 10.9 %

Weight fraction of fiber = (W_j + W_g/ W_j + W_g + W_m + W_h) ×100 = 17.38 %

S5 (JGJGJJGJGJ):- 60% Jute, 40% Glass

Weight of Jute =W_j= 5.8 gm

Weight of Glass =W_g = 6 gm

Volume of Jute (V_j)= 5.8/ρ_j = 5.8/1.5= 3.86 cc

Volume of Glass(V_g)= 6/ρ_g = 6/2.5= 2.4 cc

Volume of matrix= V_m= V_{mold} – V_j = 43.14 cc

Weight of matrix =W_m= V_m× ρ_m= 43.14×1.1= 47.45 gm

Weight of hardener = W_h= W_m/10 = 4.75 gm

Volume fraction of fiber = V_{fiber}/V_{mold} = 3.86 + 2.4/49.4= 12.67 %

Weight fraction of fiber = (W_j + W_g/ W_j + W_g + W_m + W_h) ×100 = 18.43 %

S6 (GJJGJJGJJG):- 60% Jute, 40% Glass

Weight of Jute =W_j= 5.85 gm

Weight of Glass =W_g = 6.2 gm

Volume of Jute (V_j)= 5.85/ρ_j = 5.85/1.5= 3.86 cc

Volume of Glass(V_g)= 6.2/ρ_g = 6.2/2.5= 2.5 cc

Volume of matrix= V_m= V_{mold} – V_j = 43.14 cc

Weight of matrix =W_m= V_m× ρ_m= 43.14×1.1= 47.45 gm

Weight of hardener = W_h= W_m/10 = 4.75 gm

Volume fraction of fiber = V_{fiber}/V_{mold} = 3.86 + 2.5/49.4= 12.87 %

Weight fraction of fiber = (W_j + W_g/ W_j + W_g + W_m + W_h) ×100 = 18.7 %

S7 (GJGJGGJGJG):- 40% Jute, 60% Glass

Weight of Jute =W_j= 3.5 gm

Weight of Glass =W_g = 7.8 gm

Volume of Jute (V_j)= 3.5/ρ_j = 3.5/1.5= 2.3 cc

Volume of Glass(V_g)= 7.8/ρ_g = 7.8/2.5= 3.12 cc

Volume of matrix= V_m= V_{mold} – V_j = 44 cc

Weight of matrix =W_m= V_m× ρ_m= 44×1.1= 48.4 gm

Weight of hardener = W_h= W_m/10 = 4.84 gm

Volume fraction of fiber = V_{fiber}/V_{mold} = 2.3 + 3.12/49.4= 11.05 %

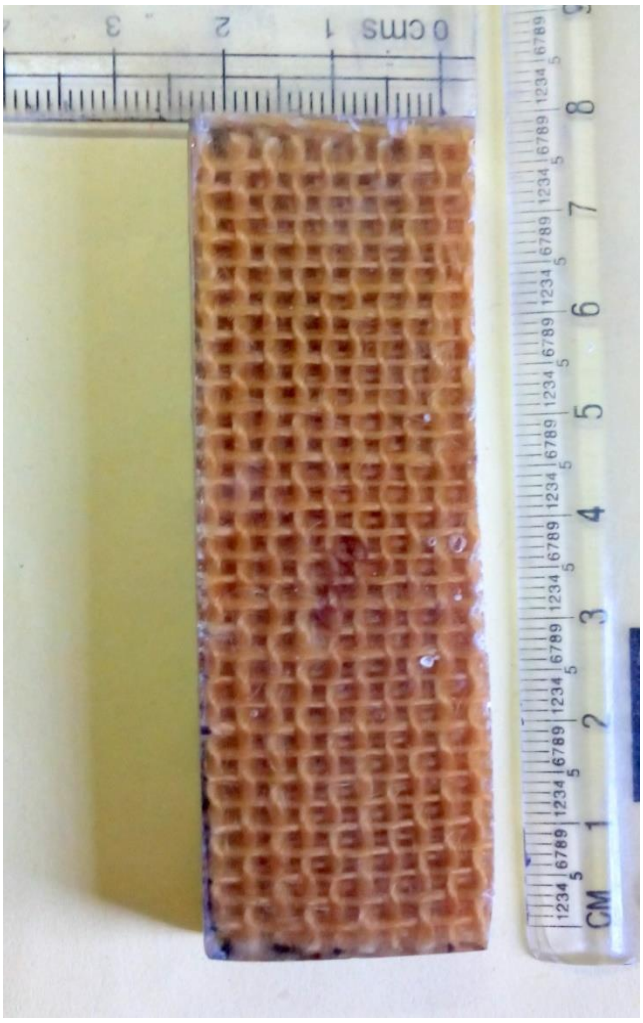
Weight fraction of fiber = (W_j + W_g/ W_j + W_g + W_m + W_h) ×100 = 17.5 %

3.2 CUTTING OF THE COMPOSITES:-

After fabrication of composites, the samples need to be cut into pieces according to the specific dimension to use them on the testing machine. The sample size to be used in the dry sand abrasive test rig is 76mm×25mm. the size of the original samples just after fabrication are 76mm×50mm. hence each sample is to be cut into two equal pieces. The samples were marked by the marker and then cut into pieces by the hacksaw. The best 7 samples were selected out of 14 samples for the experiment purpose.

The samples, before and after cutting, are shown in the figure below. The samples were marked properly to distinguish them properly according to their composition.

Before Cutting



After Cutting

All Samples

Fig. 6 (SAMPLES)

3.3 DENSITY MEASUREMENT:-

As the stacking sequences of all the composites are different, so they have different composition. Hence the density of all the seven composites will be different. The densities of all the seven composites which are prepared for testing are to be measured.

The density was measured by density measurement equipment called **"Pychnometer"**. The initial weight and density were noted.

Sample	Initial Weight	Density(gm./cc)
S1(JJJJJJJJJ)	20.420	1.198
S2(GJJJJJJJJG)	21.510	1.218
S3(GGJJJJJJGG)	20.102	1.245
S4(GGGJJJJGGG)	24.351	1.233
S5(JGJGJJGJGJ)	22.430	1.229
S6(GJJGJJGJJG)	21.542	1.246
S7(GJGJGGJGJG)	24.732	1.246

Chapter 4

ABRASION TESTING

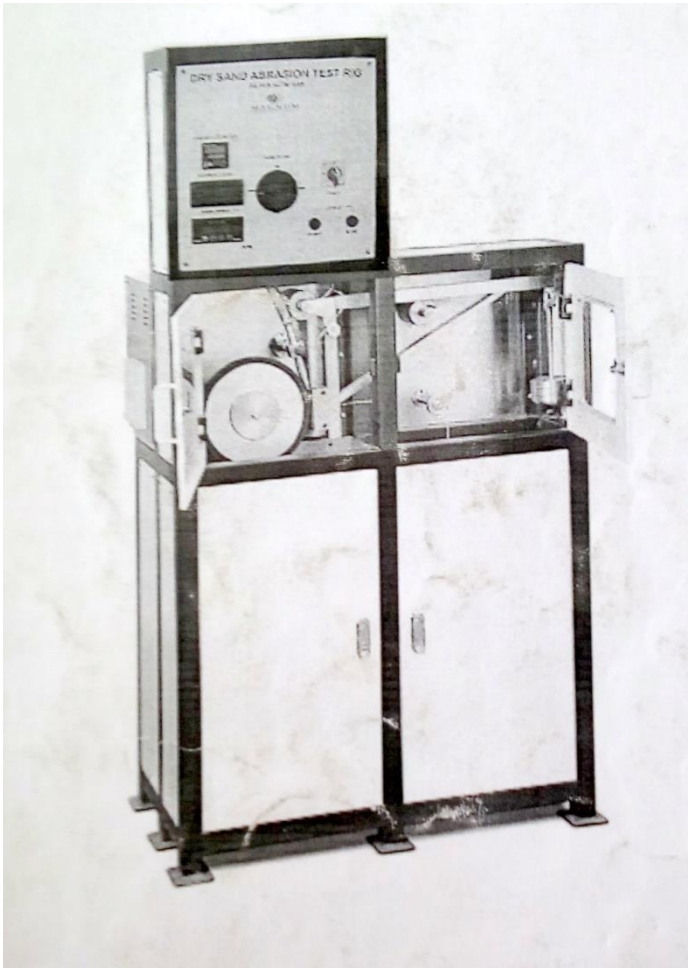
CHAPTER 4

4. ABRASION TESTING:-

The abrasion testing of the fabricated composites was done by DRY SAND ABRASIVE TEST RIG available in the laboratory.

4.1 DRY SAND ABRASION TESTING:-

Dry sand / Rubber wheel abrasion test (shown in fig. 6) involves the abrading of standard test specimen with grits of specific size and composition. The abrasive (dry sand) is introduced between the test specimen and a rotating chloro-butyl rimmed rubber wheel of a specific hardness. Angular silica sand of size 150-250 µm with sharp edges was used as abrasive. The samples were cleaned with acetone in ultrasonic cleaner and then dried. The initial weight was measured using an electronic balance having sensitivity of 0.1 mg. this was done by the pychnometer in the laboratory.



FRONT VIEW

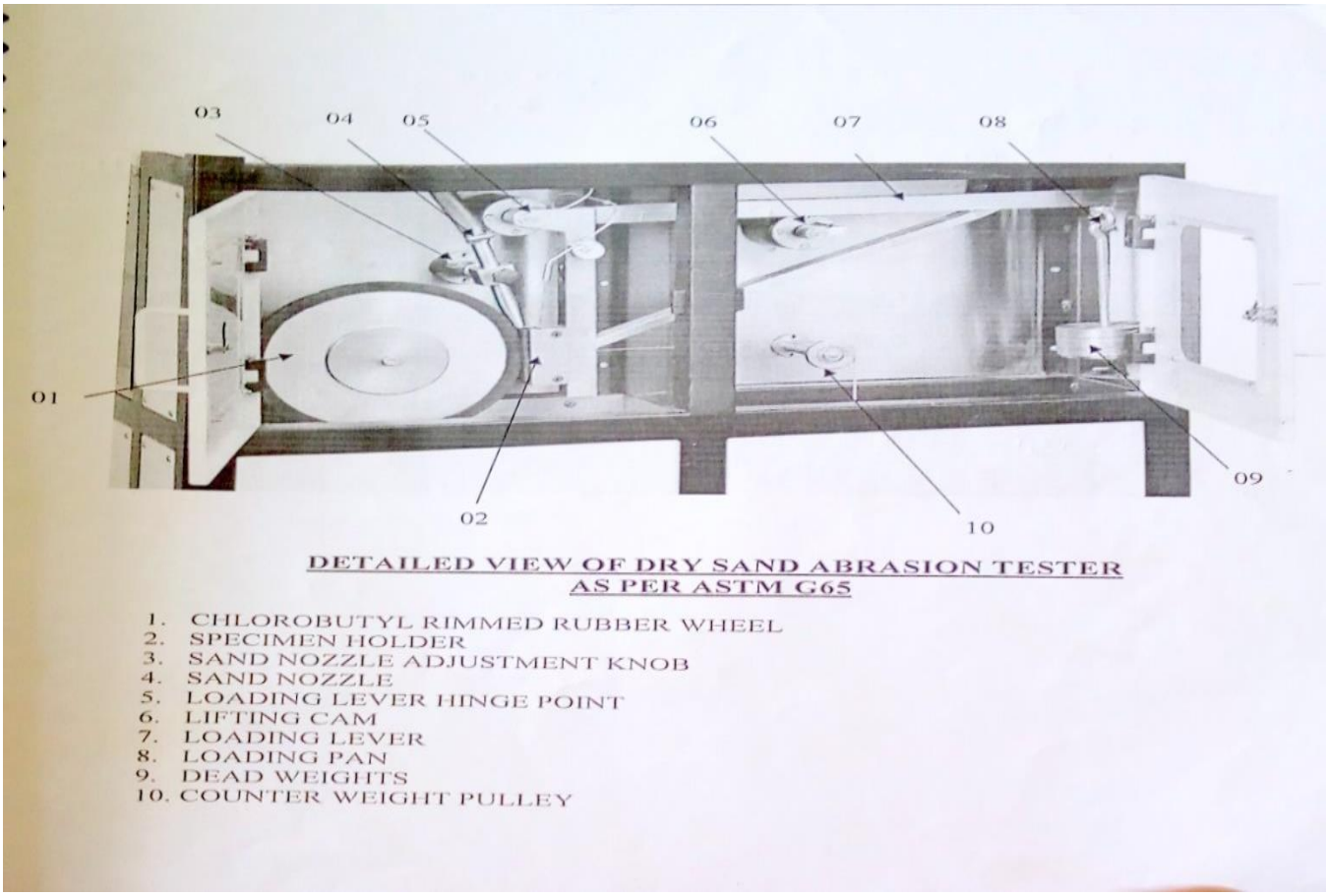


Figure 7. Dry Sand Abrasion Test RIG

The samples were then mounted on the specimen holder and pressed against the chloro-butyl rubber wheel by means of lever arm the dead weight was varied by 5N, 10N and 15N by varying the load by 500gm, 1kg and 1.5kg respectively. The flow of abrasive (dry sand) is controlled by the nozzle. The flow was set to be 200 gm. /min.

The pivot axis of the lever arm lays in-plane, tangential to the rubber wheel surface and normal to the horizontal diameter along which the load was applied. The silica (dry sand) should be moisture free and the sand should be allowed to fall under gravity.

The rubber wheel was rotated by a motor through timer belt so that it rotates with 200revolutions per minute (200rpm). The contacting surface of the rubber wheel was in the direction of flow of sand. All tests were performed in dry environment at laboratory room temperature.

TEST CONDITIONS:-

Test Variables	Test Parameters
Load	5N, 10N, 15N
Rotational speed of Rubber Wheel	200 rpm (V=2.4 m/s)
Abrasive Particles	Silica Sand(angular)
Abrasive Size	150-250 µm
Diameter of Rubber Wheel	228 mm (r=114 mm)
Specimen Size	$76\times25\times10$ mm^3
Test Duration	1 min.
Sand Flow Rate (M_a)	200 gm. /min

4.2 TEST PROCEDURE:-

The specimen was mounted on the specimen holder properly so that it does not vibrate inside it while operation. Proper weights were added subsequently to the lever arm to produce proper force to press the specimen against the wheel. Then the lever arm is lowered by the lifting cam in order to press the specimen against the rubber wheel. The number of revolution was set on the machine as 200 rpm which makes the test timing 1 minute.

Then the sand flow was initiated between the rubber wheel and the specimen. When proper uniform sand flow has occurred the wheel rotation started. The rotation of the abrasive wheel was such that its contacting face moves in the direction same as that of sand flow. The pivot axis of the lever arm lies within a plane, it is approximately tangent to the rubber wheel surface and is perpendicular to the horizontal diameter along which the load is applied. After the wheel has rotated desired number of revolutions it was stopped. The specimen was lifted using the lifting cam and hence the sand flow was also stopped.

The specimen was removed and reweighted in the pychnometer to the nearest 0.001 gm. The test was repeated for 33 times by varying the load by 5N, 10N, 15N and the measured weights were noted every time. Similar tests were carried out for the entire seven specimen and the weights were noted.

N.B.:- The specimen should be cleaned properly by acetone after each test and before the weight measurement.

4.3 OBSERVATION & TABULATION:-

FOR S1 (JJJJJJJJJJ) – ρ_1= 1.198 gm./cc, M_a= 200 gm./min

Sl. No.	Load(N)	Initial Wt.(gm.)	Final Wt.(gm.)	Wt. Diff.(gm.)	Wear Vol.(mm^3)	Wear Rate (mm^3/gm.)	Specific Wear Rate(mm^3/Nm)
1	5	20.420	20.409	0.011	9.182	0.046	1.282
2	10	20.409	20.366	0.043	35.90	0.179	2.506
3	15	20.366	20.264	0.102	85.142	0.425	3.962

FOR S2 (GJJJJJJJJG) – ρ_2= 1.218 gm./cc, M_a= 200 gm./min

Sl. No.	Load(N)	Initial Wt.(gm.)	Final Wt.(gm.)	Wt. Diff.(gm.)	Wear Vol.(mm^3)	Wear Rate (mm^3/gm.)	Specific Wear Rate(mm^3/Nm)
1	5	21.510	21.493	0.017	13.957	0.070	1.948
2	10	21.493	21.413	0.080	65.681	0.328	4.585
3	15	21.413	21.309	0.109	89.490	0.447	4.165

FOR S3 (GGJJJJJJGG) – ρ_3= 1.245 gm./cc, M_a= 200 gm./min

Sl. No.	Load(N)	Initial Wt.(gm.)	Final Wt.(gm.)	Wt. Diff.(gm.)	Wear Vol.(mm^3)	Wear Rate (mm^3/gm.)	Specific Wear Rate(mm^3/Nm)
1	5	20.102	20.096	0.006	4.82	0.024	0.673
2	10	20.096	20.044	0.052	41.767	0.209	2.915
3	15	20.044	19.948	0.096	77.108	0.385	3.588

FOR S4 (GGGJJJJGGG) – ρ_4= 1.233 gm./cc, M_a= 200 gm./min

Sl. No.	Load(N)	Initial Wt.(gm.)	Final Wt.(gm.)	Wt. Diff.(gm.)	Wear Vol.(mm^3)	Wear Rate (mm^3/gm.)	Specific Wear Rate(mm^3/Nm)
1	5	24.351	24.342	0.009	7.300	0.036	1.020
2	10	24.342	24.315	0.027	21.898	0.109	1.530
3	15	24.315	24.253	0.062	50.284	0.251	2.340

FOR S5 (JGJGJJGJGJ) – ρ_5= 1.229 gm./cc, M_a= 200 gm./min

Sl. No.	Load(N)	Initial Wt.(gm.)	Final Wt.(gm.)	Wt. Diff.(gm.)	Wear Vol.(mm^3)	Wear Rate (mm^3/gm.)	Specific Wear Rate(mm^3/Nm)
1	5	22.430	22.416	0.014	11.391	0.057	1.590
2	10	22.416	22.389	0.027	21.97	0.110	1.533
3	15	22.389	22.346	0.043	34.987	0.175	1.630

FOR S6 (GJJGJJGJJG) – ρ_6= 1.246 gm./cc, M_a= 200 gm./min

Sl. No.	Load(N)	Initial Wt.(gm.)	Final Wt.(gm.)	Wt. Diff.(gm.)	Wear Vol.(mm^3)	Wear Rate (mm^3/gm.)	Specific Wear Rate(mm^3/Nm)
1	5	21.542	21.511	0.031	24.88	0.124	3.473
2	10	21.511	21.453	0.058	46.55	0.233	3.250
3	15	21.453	21.360	0.093	74.634	0.373	3.473

FOR S7 (GJGJGGJGJG) – ρ_7= 1.248 gm./cc, M_a= 200 gm./min

Sl. No.	Load(N)	Initial Wt.(gm.)	Final Wt.(gm.)	Wt. Diff.(gm.)	Wear Vol.(mm^3)	Wear Rate (mm^3/gm.)	Specific Wear Rate(mm^3/Nm)
1	5	24.732	24.721	0.011	8.814	0.044	1.230
2	10	24.721	24.679	0.042	33.654	0.168	2.350
3	15	24.679	24.602	0.078	62.500	0.312	2.908

4.4 FORMULAE & SAMPLE CALCULATION:-

Wear volume = V (mm^3)

Wear rate = W_r (mm^3/gm.)

Specific wear rate = K_0 (m^3/Nm)

Density of material = ρ (gm./cc)

Mass of abrasive = M_a (gm.) = 200 gm/min

Load (L) = 5N, 10N, 15N

Sliding Distance = D (m)

Here, Sliding distance = D= $2\pi rNt$

Where, r = radius of rubber wheel = 11mm

N = RPM =200

t = time = 1 min.

So, Sliding Distance = D = $2\pi rNt$

$= 2\pi \times 114 \times 200 \times 1$

= 143256.625 mm

⇨ **D = 143.25 m**

- Wear Volume = V = $m_2 - m_1 / \rho$ (mm^3)

  Where, ($m_2 - m_1$) is wt. difference
- Wear Rate = $W_r = V / M_a$ (m^3/gm)
- Specific Wear Rate = $K_0 = V / LD$(m^3/Nm)

SAMPLE CALCULATION:-

For Sample 1 (S1) :-

$m_2 - m_1$ = 0.011 gm, Load = 5N

- Wear Volume = V = $m_2 - m_1 / \rho$ = 0.011/ 1.198 = 9.182 mm^3
- Wear Rate = $W_r = V / M_a$ = 9.182/200 = 0.046 mm^3/min
- Specific Wear Rate = $K_0 = V / LD = 1.282 \times 10^{-11}$ m^3/Nm

Chapter 5

RESULTS & DISCUSSIONS

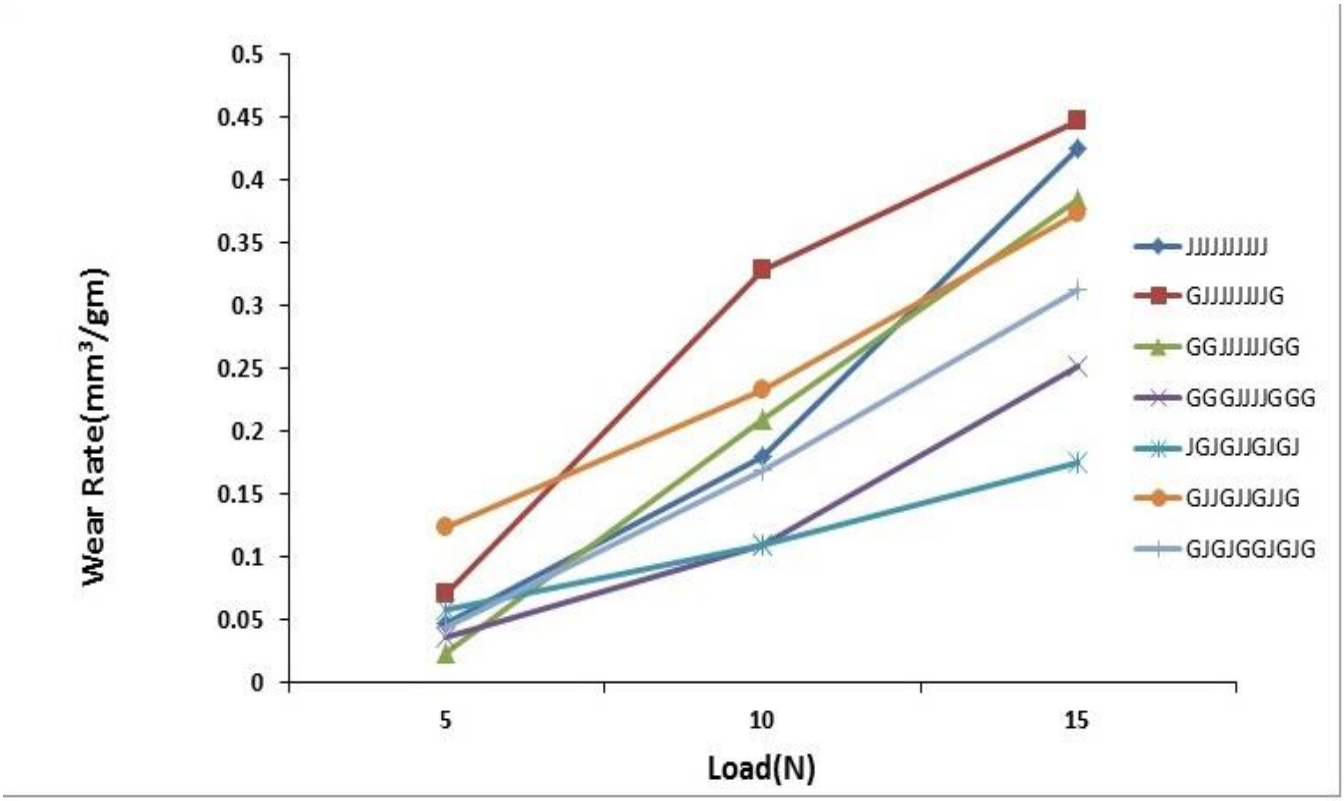
CHAPTER 5

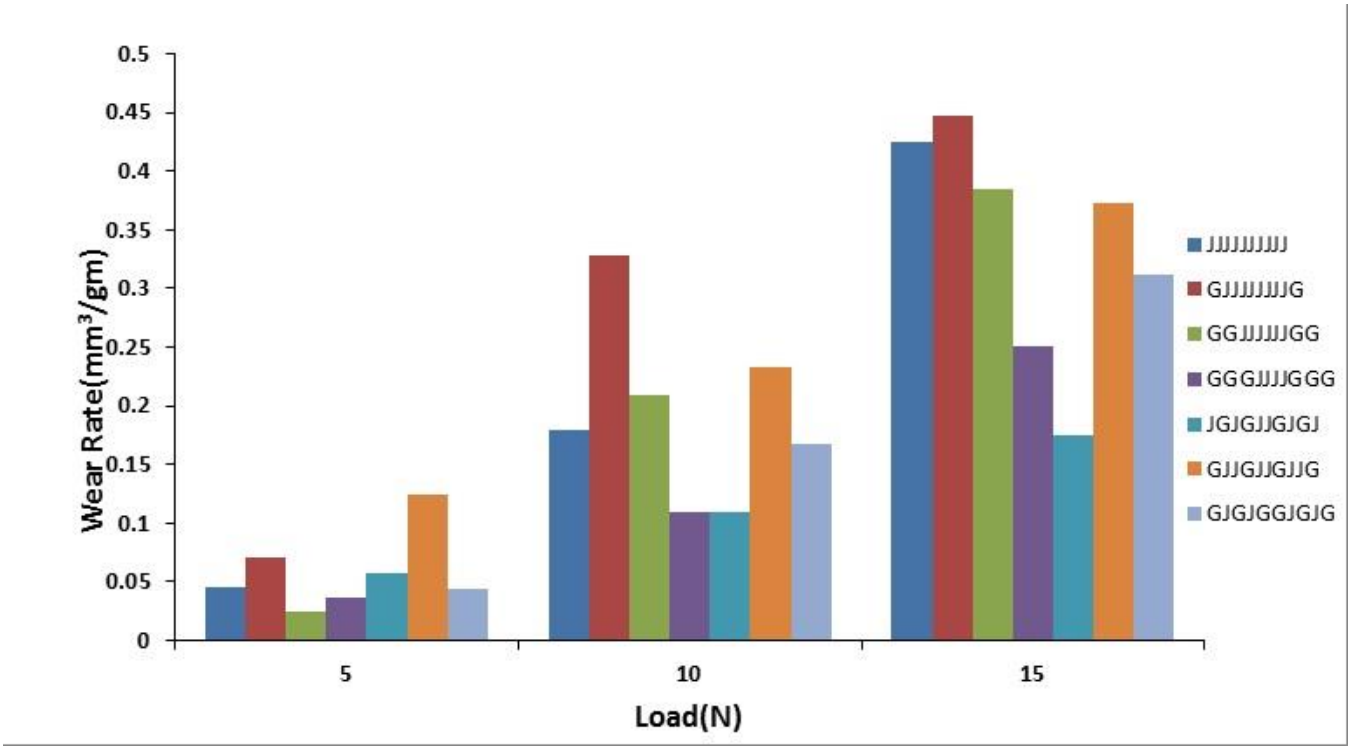
5. RESULTS & DISCUSSIONS:-

In the previous chapter we have calculated the values of wear volume, wear rate and specific wear rate for all the seven composites. In this chapter we will discuss how these values behave for different composition or stacking sequence of the composites.

The rate of material removal depends on various factors like load, rpm, flow of sand particles, density of the specimen, nozzle angle etc. In this experiment we have varied the load by 5N (5N, 10N, 15N) and all other parameters remains constant.

5.1 WEAR RATE:-





The wear rate increases with increasing load. As the load increases the specimen is pressed more to the rubber wheel and more frictional loss occurs which causes more loss of material from the surface.

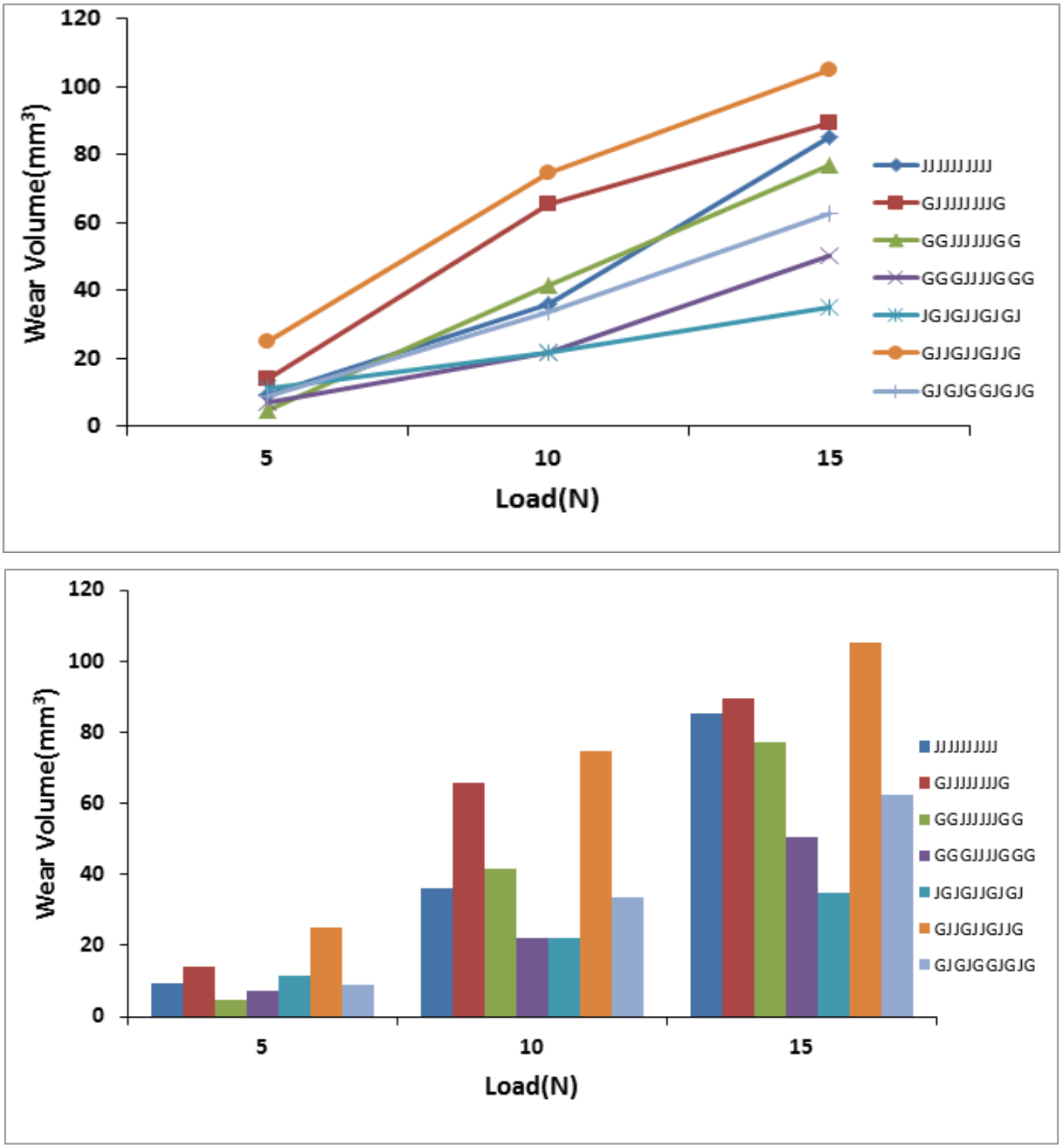
When the load is less (5N) wear rate remains very low in the range of 0 to 0.1 mm^3/gm for all type of stacking sequence. But as the load increases the increase in wear rate becomes more visible. For 10N load the wear rate remains in the range of 0.1 to 0.3 mm^3/gm, which is a little bit higher. Further increasing the load to 15N the wear rate remains in the range of 0.15 to 0.5 mm^3/gm.

It is also observed that if the composite has glass fiber on the outer side then wear rate becomes less. The wear rate of S4 and S7 are very much lower than that of S1, S2, S3 and S6. The reason is glass is more wear resistant than jute.

Order of Wear rate is given by:-

S2 > S1 > S3 > S6 > S7 > S4 > S5 (15N Load)

5.2 WEAR VOLUME:-



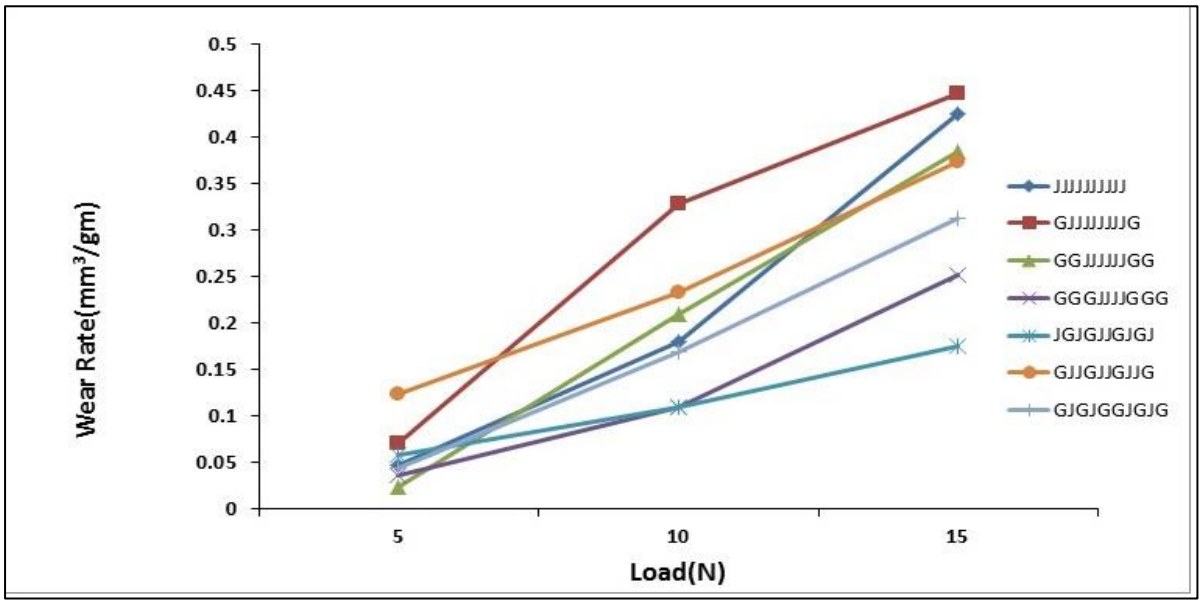
It is the amount of material loss measured for each specimen by applying loads of 5N, 10N, 15N.

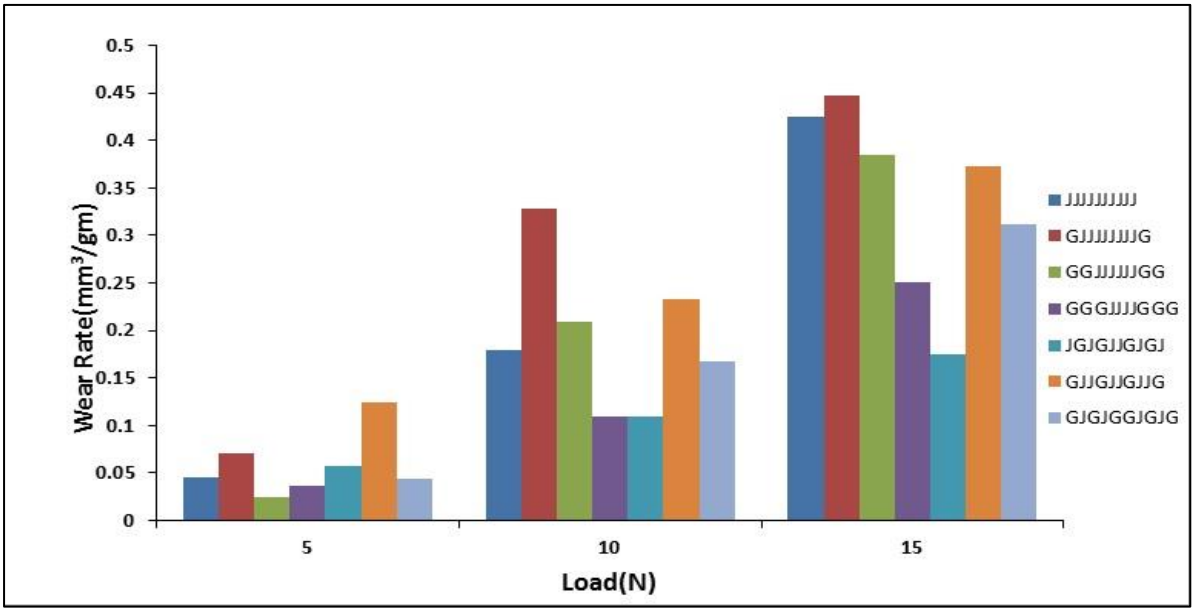
Wear volume also shows similar pattern like wear rate as wear volume is directly proportional to the wear rate. For specimen having more proportion of glass undergoes less material loss from the surface.

Order of Wear Volume is given by:-

S6 > S2 > S1 > S3 > S7 > S4 > S5 (15N Load)

5.3 SPECIFIC WEAR RATE:-





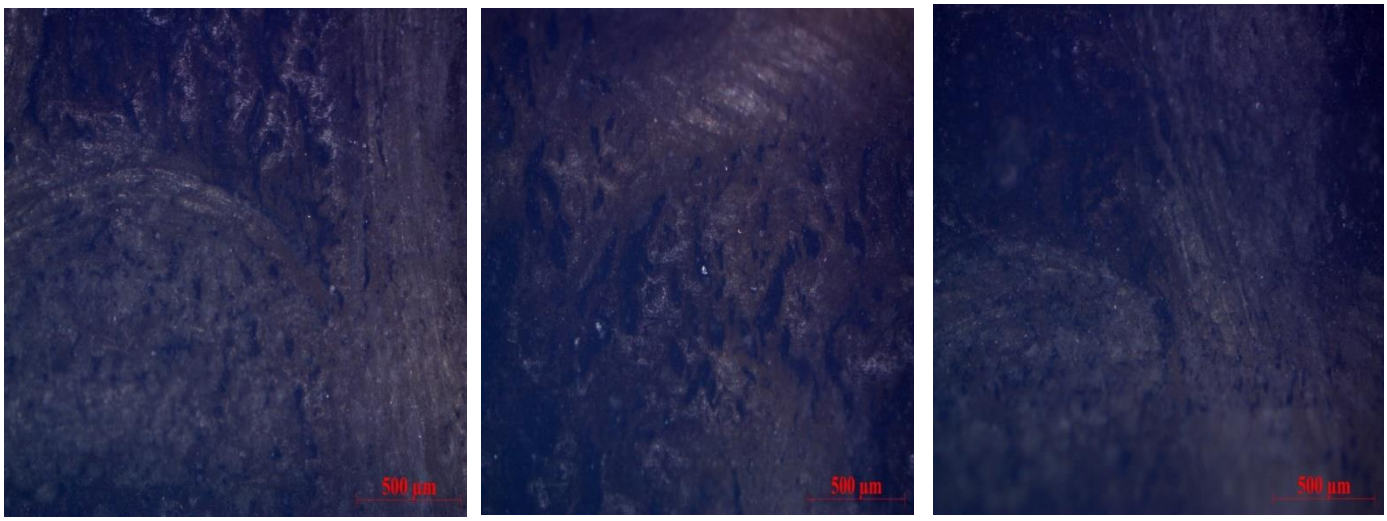
The specific wear rate depends on wear volume, load and sliding distance. Its value was different for all the three observations. Here sliding distance is constant as the rubber wheel diameter is constant. As load and wear volume varies, the specific wear rate (K_0) changes its value.

For all the seven composites the specific wear rate increases on increasing the load to 15N but for composites S2 and S6 the specific wear rate came out very high at 15N.

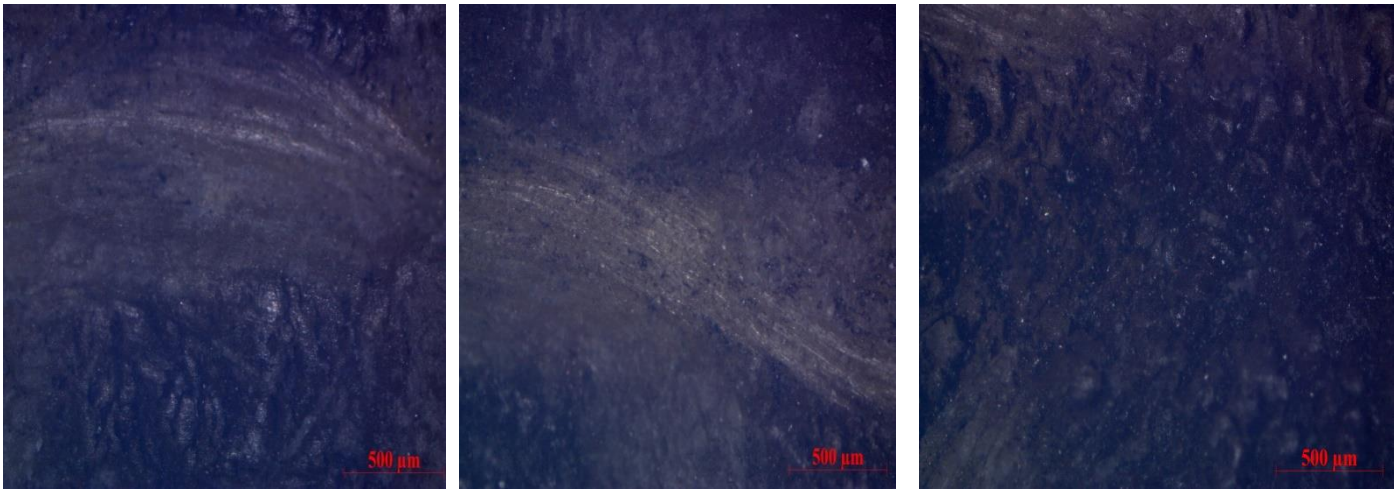
Order of Specific Wear Rate (K_0):-

S6 > S2 > S1 > S3 > S7 > S4 > S5 (15N Load)

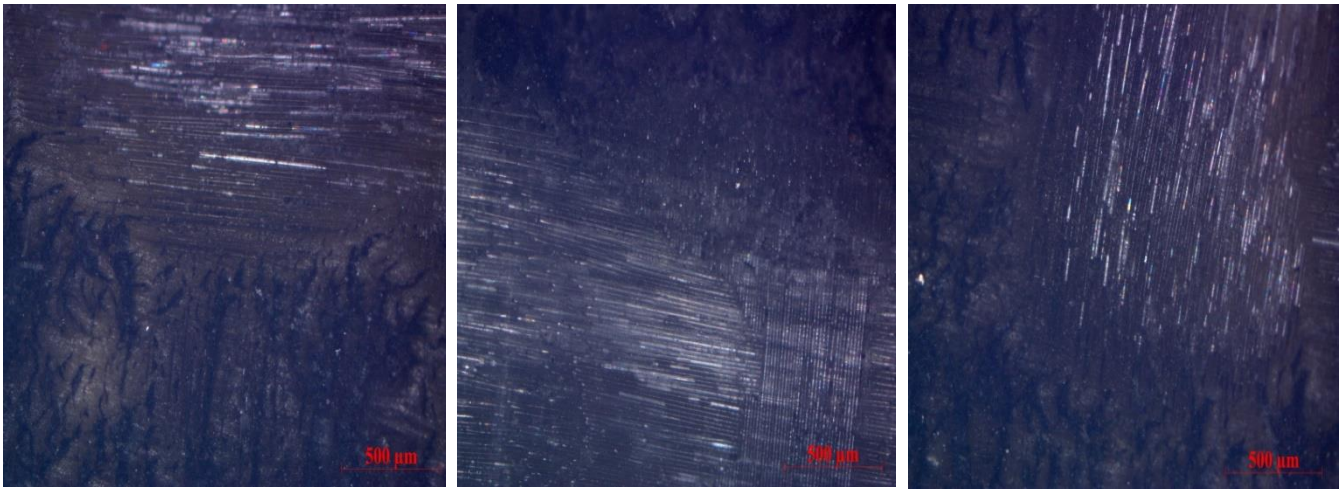
5.4 MICROSCOPIC ANALYSIS OF ABRADED SURFACE:-



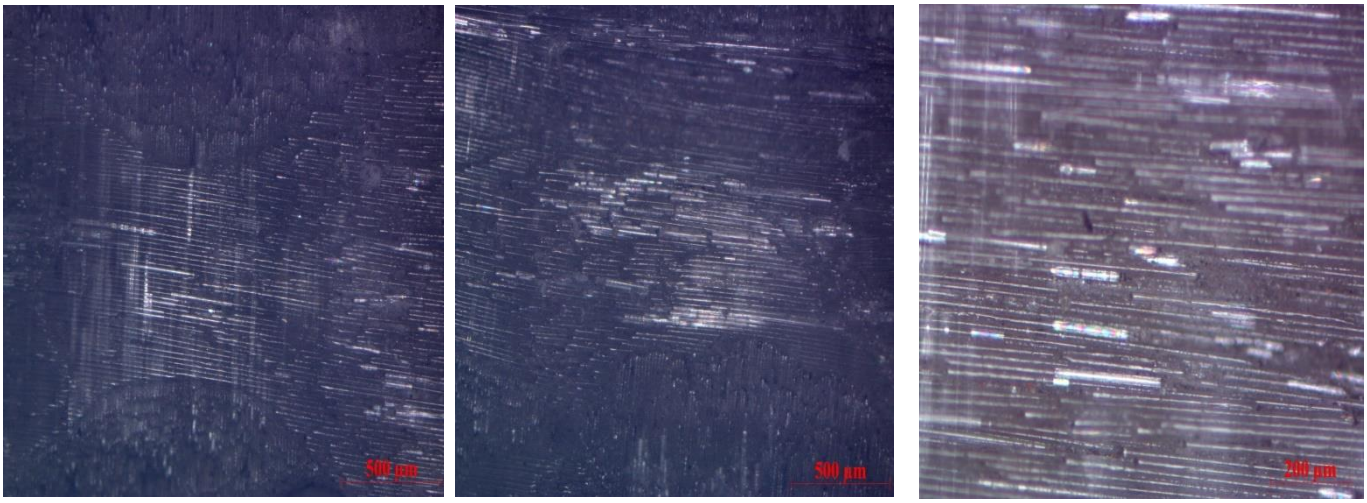
S1 (JJJJJJJJJJ)



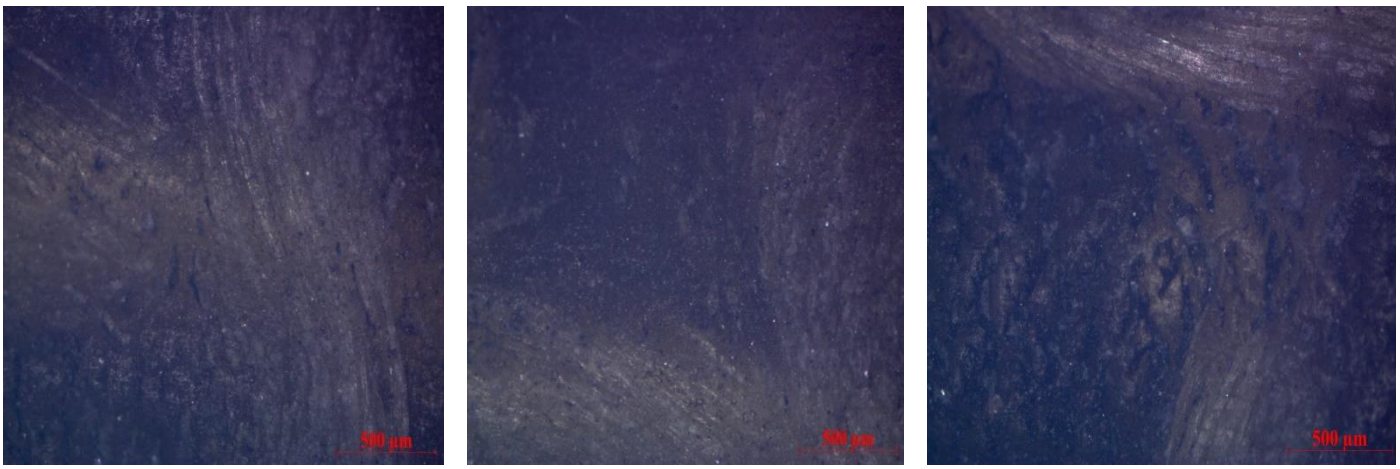
S2 (GJJJJJJJJG)



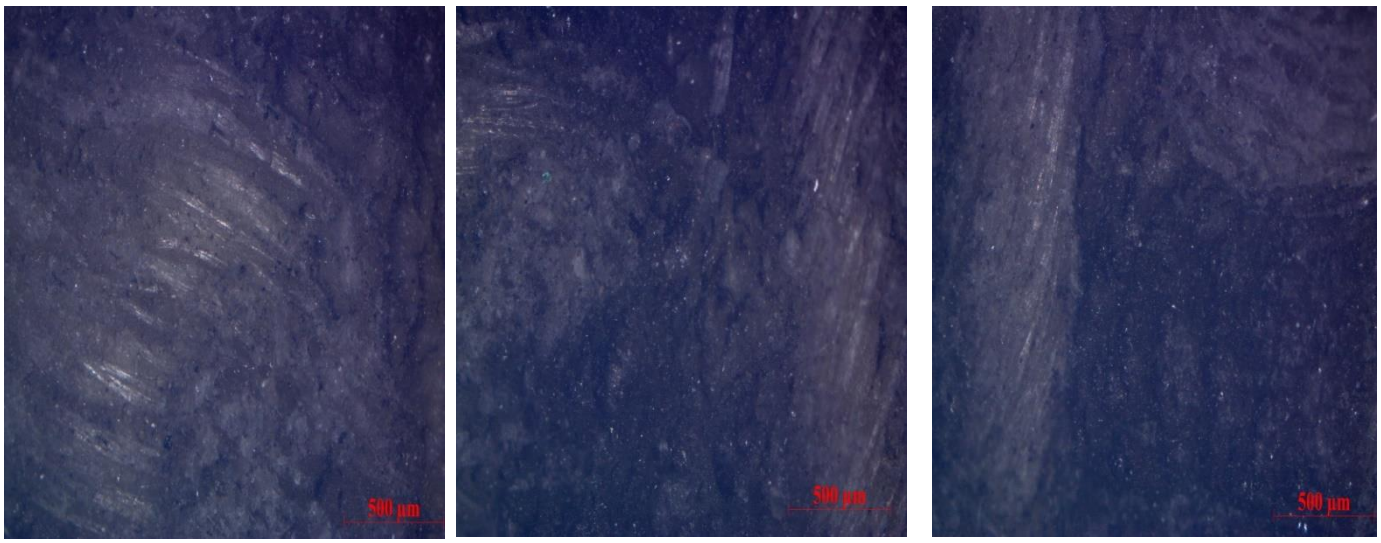
S3 (GGJJJJJJGG)



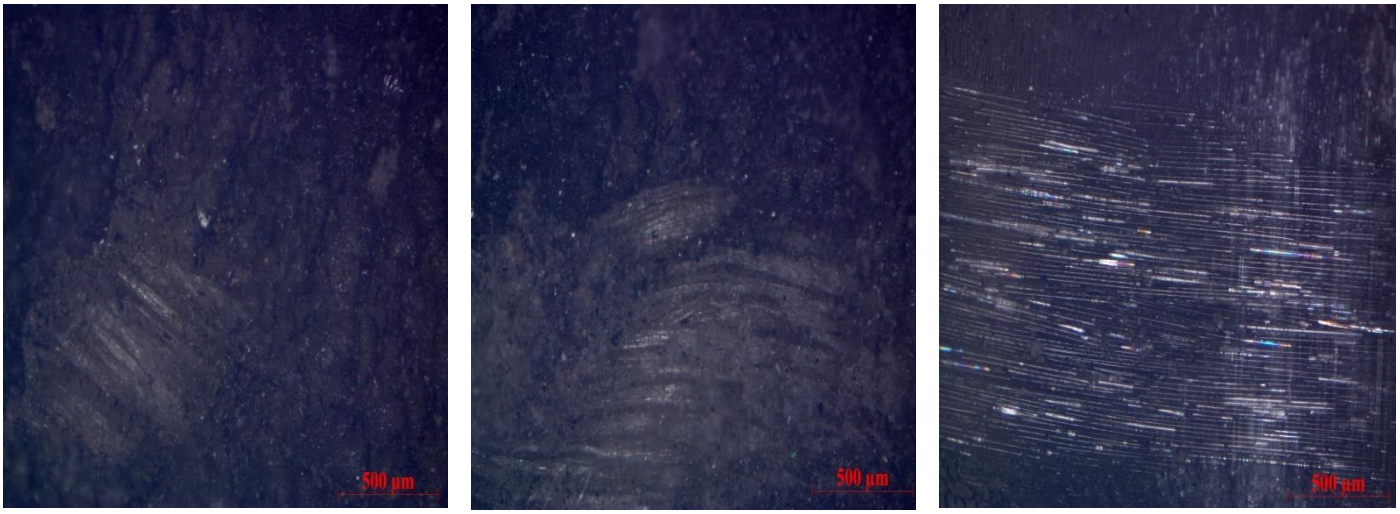
S4 (GGGJJJJGGG)



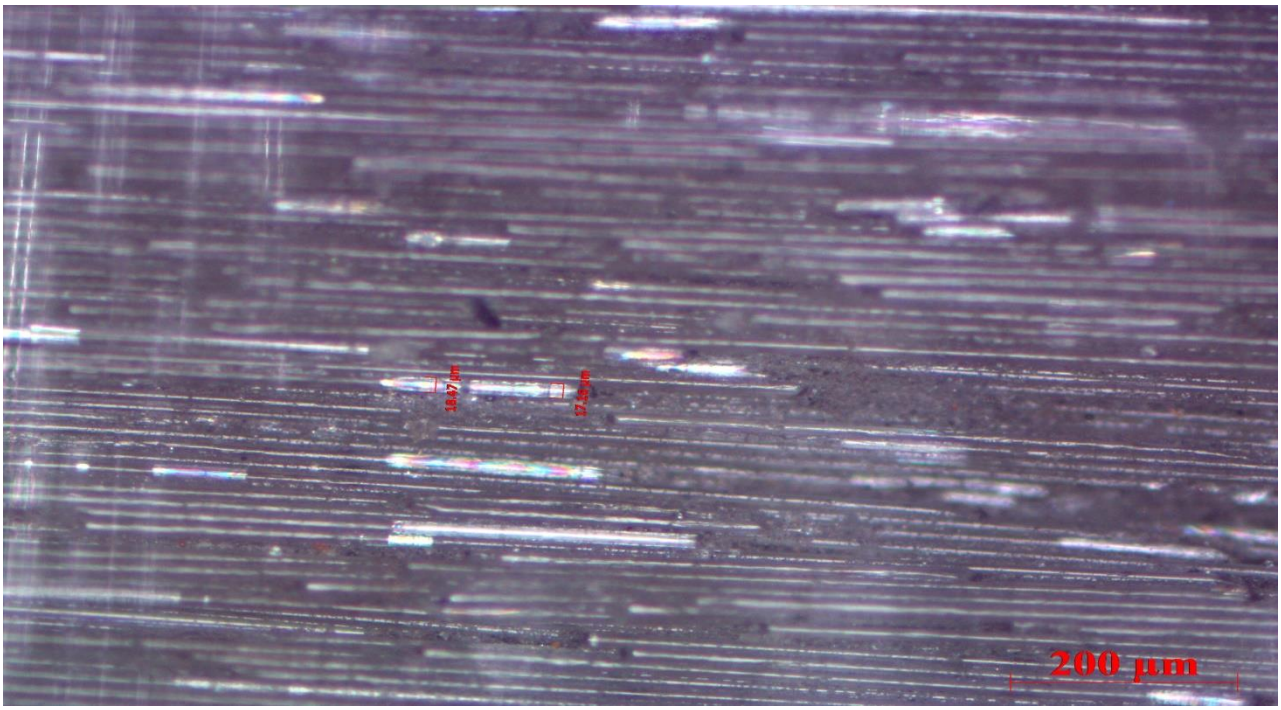
S5 (JGJGJJGJGJ)



S6 (GJJGJJGJJG)



S7 (GJGJGGJGJG)



(Diameter of Glass Fiber)

Figure 9: Microscopic Analysis

Chapter 6

CONCLUSION

CHAPTER 6

CONCLUSIONS:-

The fabrication and experimental investigation of abrasive wear behavior of Jute-Glass hybrid composites leads to the following conclusions.

1. This work shows successful fabrication of Jute-Glass composite with and without filler material.
2. The Jute-Glass composites can be fabricated by simple hand lay-up technique.
3. The abrasive wear behavior is different for different composites having different stacking sequence.
4. The results indicate that wear rate increases sharply at 15N load.
5. Composites having glass layer at the outer parts are more wear resistance than others.
6. Maximum wear rate of 0.425 mm^3/gm is obtained for S1 (JJJJJJJJJJ).
7. These fabricated composites can be used in making doors, windows, panels, floor tiles. It can also be used in aerospace engineering.

SCOPE FOR FUTURE WORK:-

In the present work, only load is varied to check the wear behavior of the composites. The other parameters like rpm of rubber wheel, flow of sand particles and nozzle angle can be varied to study the abrasive wear behavior. The composites can also be fabricated by using spray lay-up technique and filament winding instead of hand lay-up technique.

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